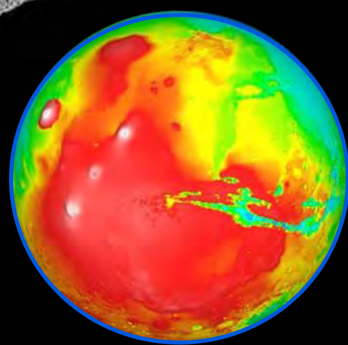
Investments in the Future: NASA's Technology Programs

Robert D. Braun
NASA Chief Technologist
April 22, 2010

Extending Human Presence Beyond Low Earth Orbit

- The goal of NASA's human spaceflight program is to extend human presence beyond low Earth orbit.
- The President's FY2011 budget request takes a new approach to this goal, focusing on developing the technological capabilities required for humans to reach multiple destinations, including the Moon, near-Earth asteroids, Lagrange points, and Mars.
- NASA's near-term investments seek to create the *knowledge* and *capabilities* required for humans to venture beyond low Earth orbit safely and efficiently.
- This approach seeks to change the game by expanding the alternatives available for human exploration through timely, strategic and significant technology investment.



External Input Has Driven Development of NASA’s Technology-Enabled Approach

- **NASA Authorization Act of 2008:** “*A robust program of long-term exploration-related research and development will be essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system.*”
- **NRC report, A Constrained Space Exploration Technology Program: A Review of NASA’s ETDP, 2008:** *“NASA has created a supporting technology program very closely coupled to the near-term needs of the Constellation Program. This program contains only incremental gains in capability and two programmatic gaps. NASA has effectively suspended research in a number of technology areas traditionally within the agency’s scope. This could have important consequences for those portions of the VSE beyond the initial short-duration lunar missions, including extended human presence on the Moon, human exploration of Mars, and beyond.”*
- **NRC report, America’s Future in Space, 2009:** “*NASA should revitalize its advanced technology development program by establishing a DARPA-like organization within NASA as a priority mission area to support preeminent civil, national security (if dual-use), and commercial space programs.”*
- **NRC report, Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts, 2009:** “*To improve the manner in which advanced concepts are infused into its future systems, the committee recommends that NASA consider reestablishing an aeronautics and space systems technology development enterprise. Its purpose would be to provide maturation opportunities and agency expertise for visionary, far-reaching concepts and technologies.”*
- **Augustine Committee, 2009:** “*The Committee strongly believes it is time for NASA to reassume its crucial role of developing new technologies for space. Today, the alternatives available for exploration systems are severely limited because of the lack of a strategic investment in technology development in past decades.*”

Consistent Set of Exploration Capability Investments

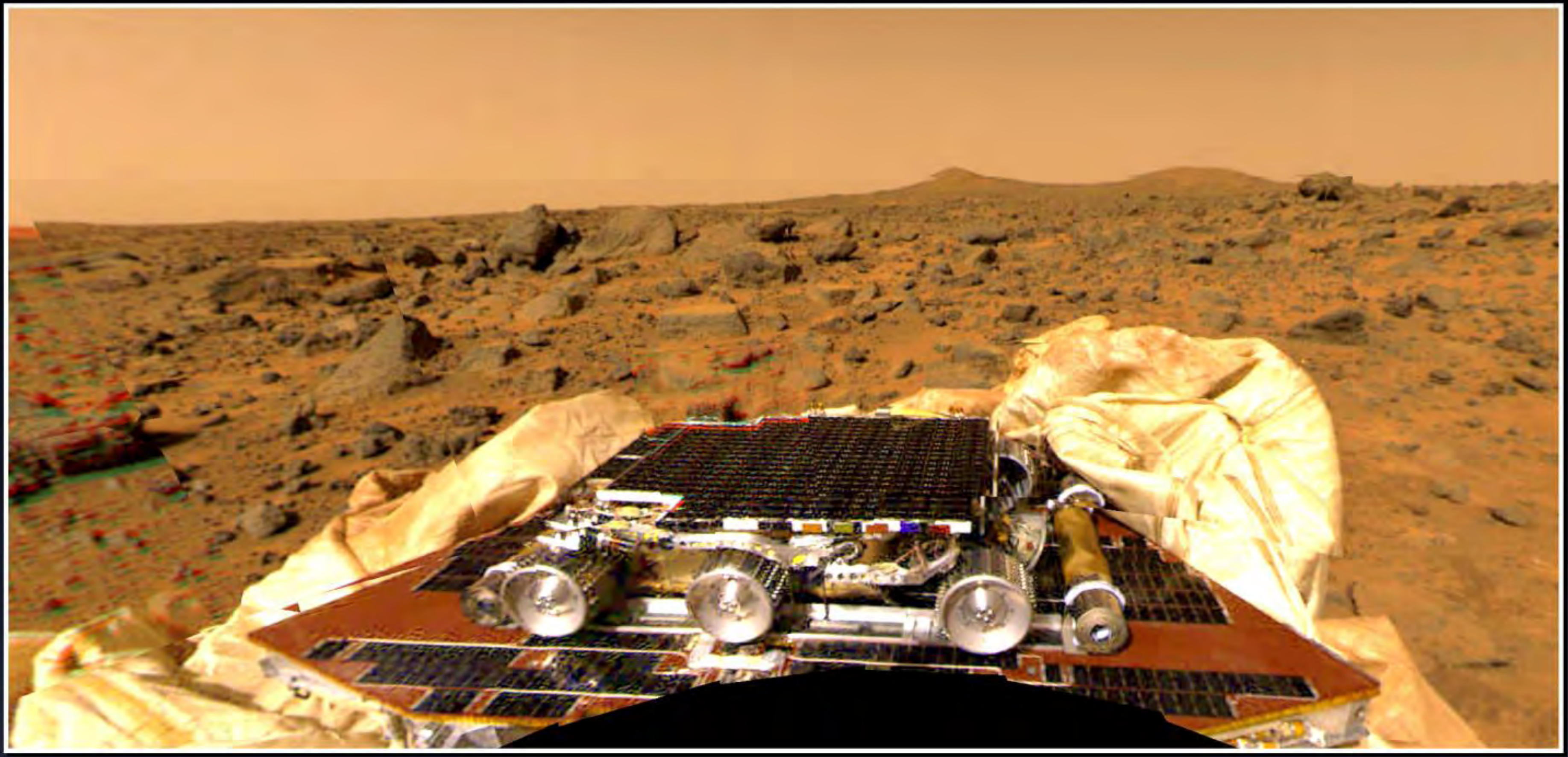
	1969 Post-Apollo Space Program (NASA STG)	1986 Pioneering the Space Frontier (Paine)	1987 America's Future in Space (Ride)	1988 Beyond Earth's Boundaries (NASA)	1989 90-Day Study (NASA)	1990 Future of U.S Space Program (Augustine)	1991 America at the Threshold, SEI (Stafford)	1997 Human Exploration of Mars DRM (NASA)	2004 President's Commission on U.S. Space Exploration Policy (Aldridge)	2009 Report of U.S. Spaceflight Committee (Augustine)
Advanced/Closed Loop Life Support		X	X	X	X	X	X	X	X	X
Advanced Power Generation & Storage (in-space and surface, Solar and nuclear)	X	X	X	X	X	X	X	X	X	X
Advanced In-Space Propulsion (chemical, solar electric, nuclear thermal, nuclear electric)	X	X	X	X	X	X	X	X	X	X
In-Space Cryo/Propellant Transfer and Storage		X	X	X	X		X	X	X	X
Heavy Lift Launch Vehicle			X	X	X	X	X	X	X	
Autonomous/Expert Systems		X	X			X		X	X	X
Robotics (tele-robotic & autonomous operation)		X	X		X	X	X	X	X	X
EDL (includes aerocapture, aerobraking, aeroentry)		X	X	X	X	X	X	X	X	X
Human Health and Performance (Radiation, gravity, psychological effects and mitigation, medical technologies)	X	X	X		X	X	X	X	X	X
Autonomous Rendezvous and Docking				X	X		X		X	X
In-Situ Resource Utilization (Lunar, NEO, and Mars based)		X	X	X	X	X	X	X	X	X
Lightweight Structures and Materials		X					X	X	X	X
Advanced In-Space Engine					X	X	X		X	X
Advanced EVA Systems		X		X	X	X	X	X	X	
Communication Technology	X				X	X	X		X	
Reliable Efficient Low Cost Advanced Access to Space	X		X							X
Reusable In-Space Transfer	X	X	X		X	X				
Surface Rovers				X			X	X		

Tenets of a Technology-Enabled Exploration Strategy

- Early stage innovation and foundational research efforts feed NASA's technology development programs.
- A steady cadence of technology demonstrations will prove the requisite flexible path capabilities, enabling a stepping-stone set of human exploration achievements.
  - This sequence of missions will begin with a set of crewed flights to prove the capabilities required for exploration beyond low Earth orbit.
  - After these initial missions, the long-duration human spaceflight capabilities matured through our technology development programs will enable human explorers to conduct the first-ever deep space human exploration missions.
- NASA's technology development programs include early investment in the long-lead capabilities needed for future deep space and surface exploration missions.
  - Needed capabilities are identified, multiple competing technologies to provide that capability are funded, and the most viable of these are demonstrated in flight so that exploration architectures can then reliably depend upon them.
  - For example, NASA's parallel path investments in heavy-lift propulsion, in-space propellant storage and transfer, and in-space propulsion technologies provide robustness and improve the viability of a future deep space human exploration capability.

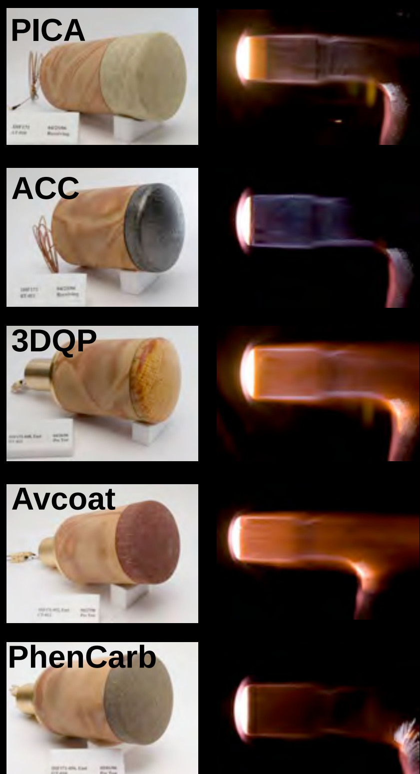
The renewed emphasis on technology in the President s FY11 budget request balances the long-standing NASA core competencies of R&T, spaceflight hardware development, and mission operations, is essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system, and recognizes the Agency as an important catalyst for innovation and economic expansion in our Nation.

Pathfinder Spacecraft on the Mars Surface — July 4, 1997



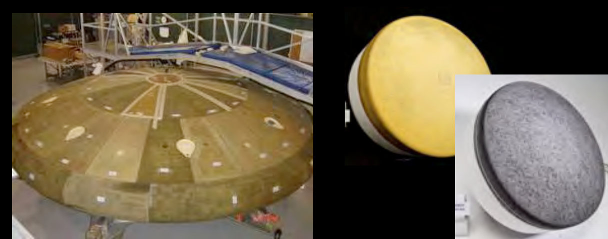
In Development Within 2 Years of Mars Pathfinder Landing

Direct Results of the Orion TPS ADP



Competitive materials R&D resulted in multiple viable materials & systems

Avcoat: Selected for the Orion



PICA: Selected for MSL & Dragon

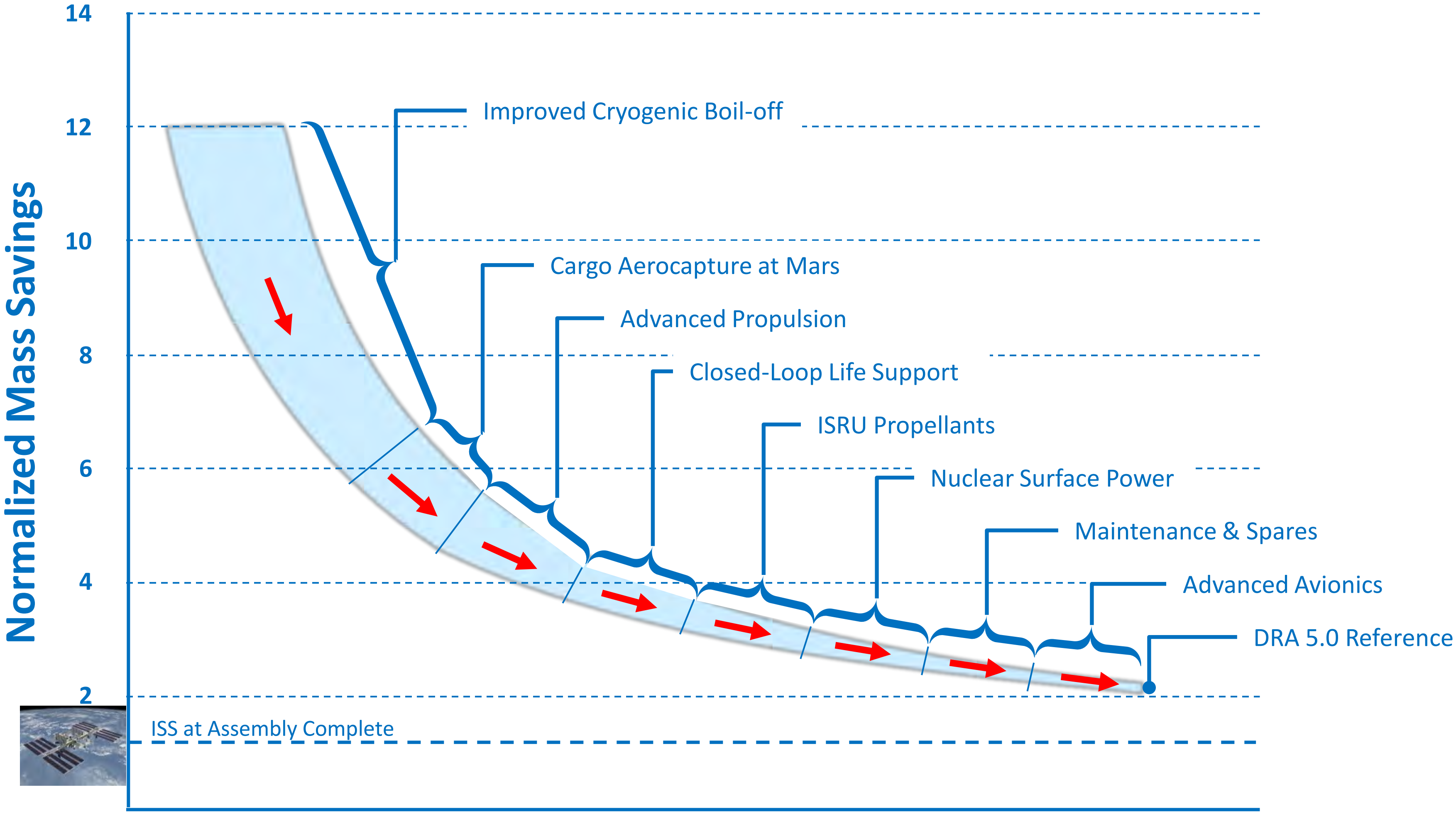
TPS ADP arcjet tests revealed catastrophic failure mode of initial MSL TPS

MSL shifts to a new TPS ADP developed TPS material

Large article arcjet testing demonstrated during TPS ADP is now a necessary TPS tool

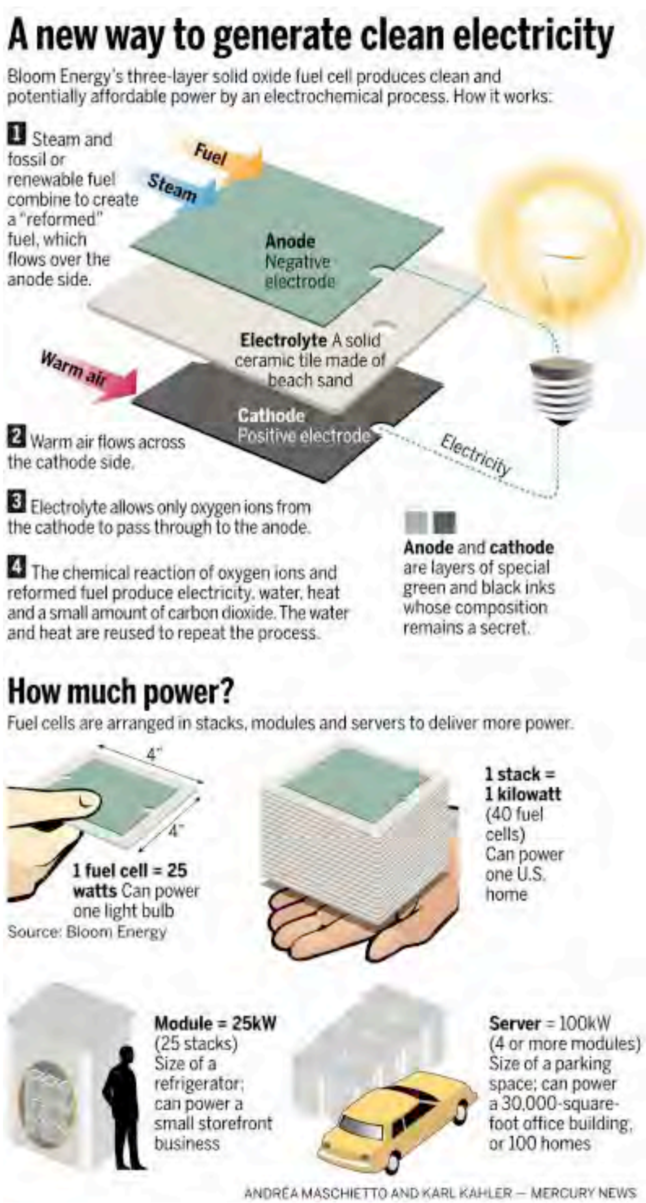
- New NASA TPS experts
- Multiple TPS firms
- Large scale manufacturing
- TRL = 5-6 ablative TPS
- Promising new TPS concepts
- Technology transfer to commercial space

The Value of Technology Investments
Mars Mission Example

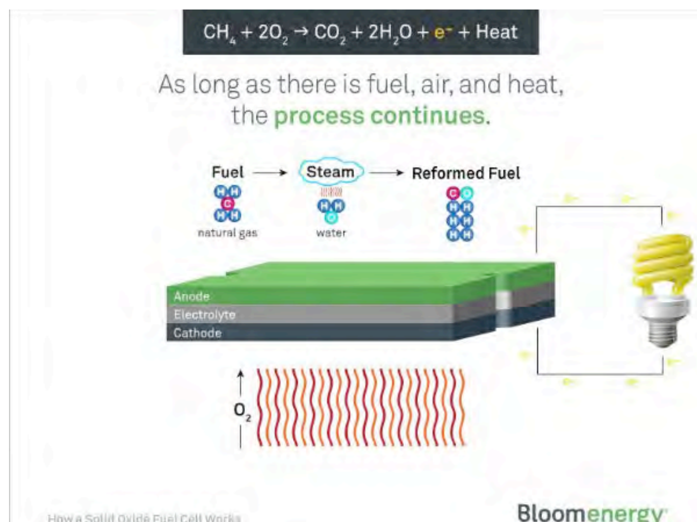


- Without technology investments, the mass required to initiate a human Mars mission in LEO is approximately twelve times the mass of the International Space Station
- Technology investments of the type proposed in the FY 2011 budget are required to put such a mission within reach

Nine Years after NASA Mars Oxygen Generator Development……



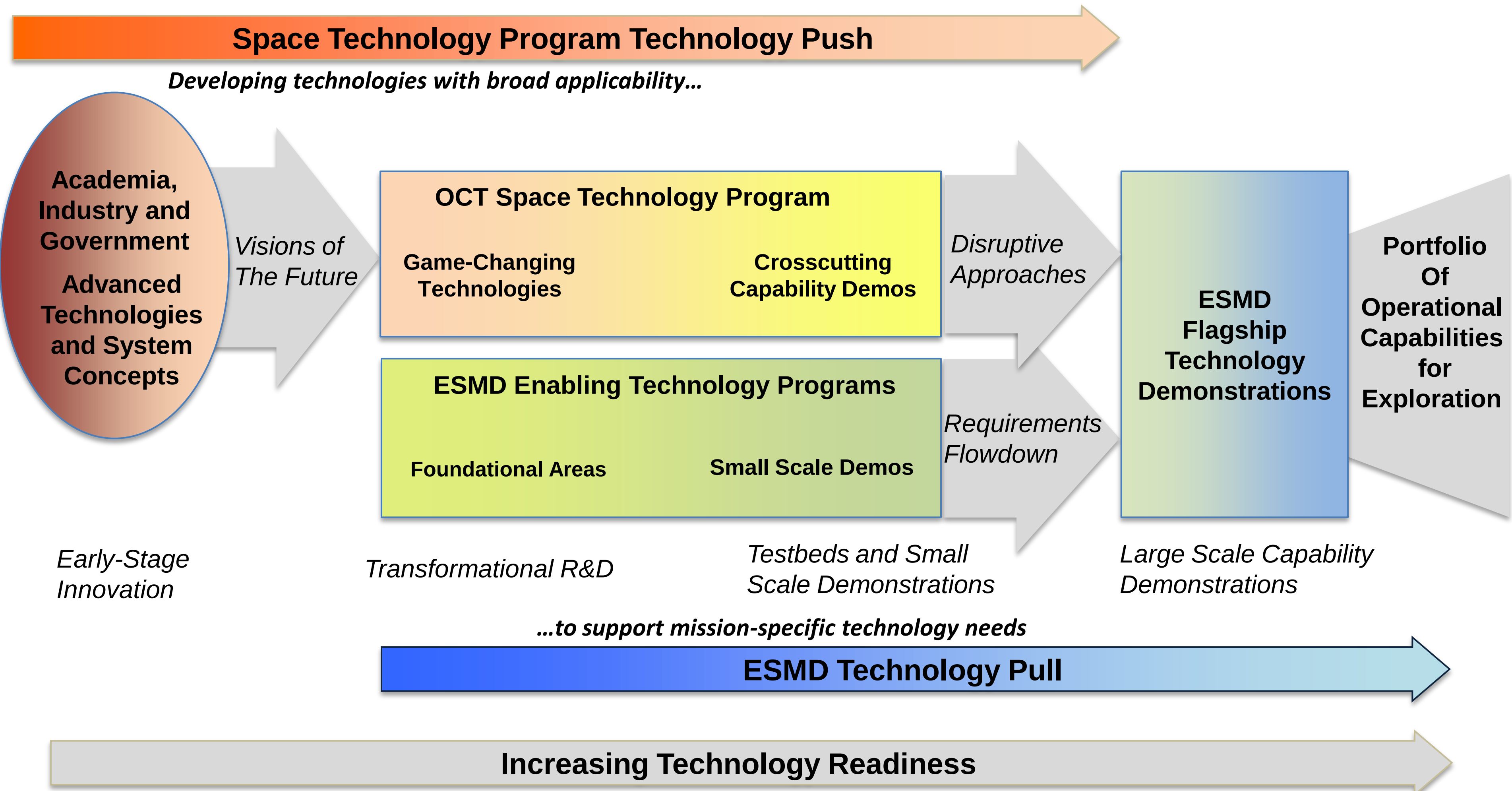
Space technology modified to generate clean power at Ebay Headquarters in San Jose, CA. Similar fuel cell systems deployed at five other customer sites. Image from www.bloomenergy.com.



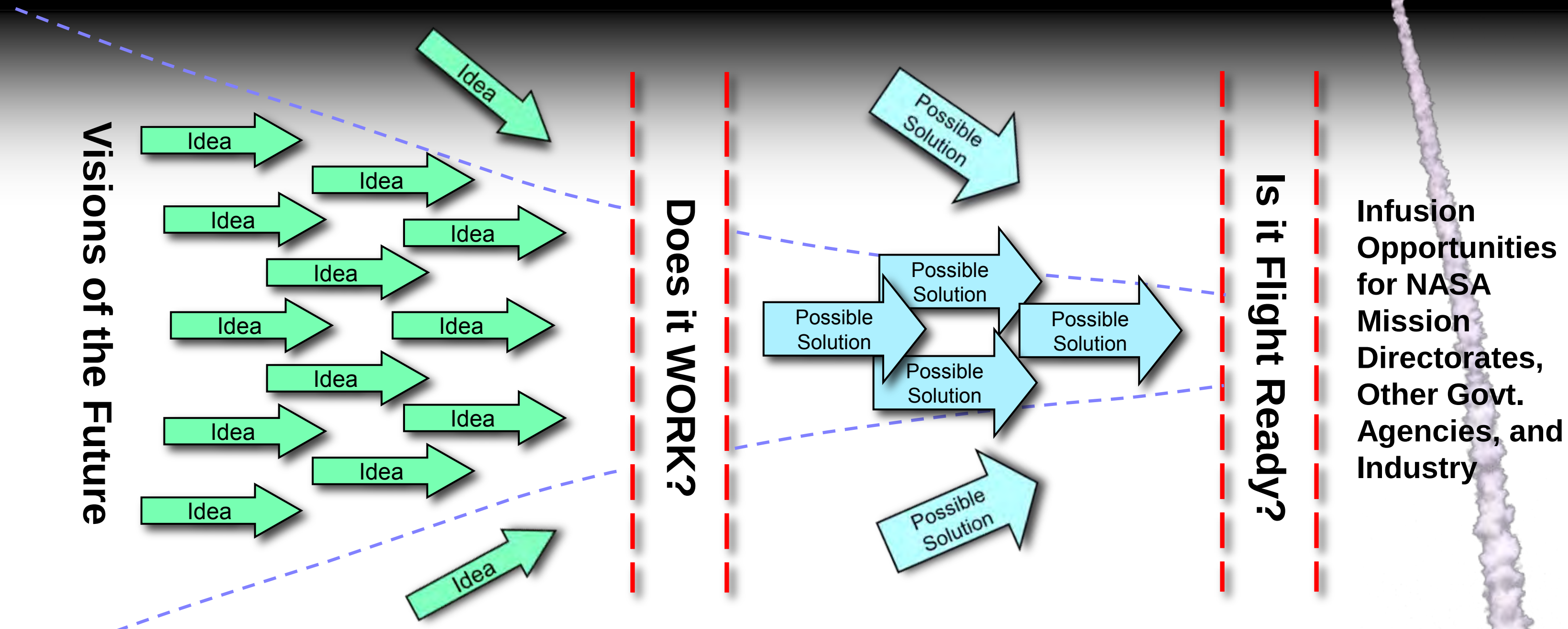
Solid Oxide Fuel Cell Described

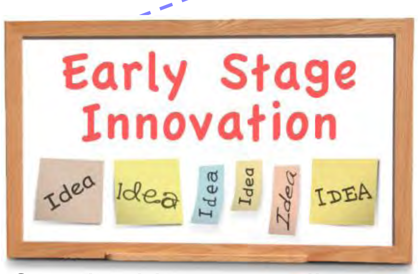
NASA's Integrated Technology Programs

- A portfolio of technology investments which will enable new approaches to NASA's current mission set and allow the Agency to pursue entirely new missions of exploration and discovery.



NASA Space Technology





Creative ideas regarding future NASA systems or solutions to national needs.

Prove ideas with the potential to revolutionize future NASA missions or fulfill national needs.

Mature crosscutting capabilities that advance multiple future space missions to flight readiness status

Potential Grand Challenges

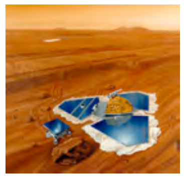
Make space access economical

Provide economical energy on demand

Develop routine satellite servicing

Forecast natural disasters

Manage climate change



Provide participatory exploration

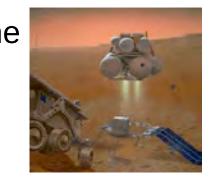
Improve spacecraft safety and reliability

Provide carbon-neutral mobility

Protect astronaut health

Engineer faster space vehicles

Unleash machine intelligence

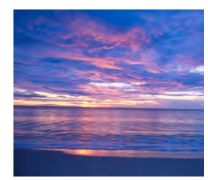


Utilize space resources to explore

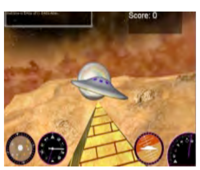
Prevent orbital debris

Secure the planet from space threats

Understand physics governing the universe

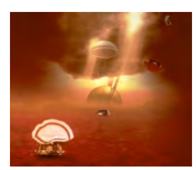


Establish conditions for permanent humans in space



Develop personalized STEM learning

Engineer the tools of scientific discovery



Discover life beyond earth

NASA Space Technology Program Foundational Principles

- The Space Technology Program shall
  - Advance non-mission-focused technology.
  - Produce technology products for which there are multiple customers.
  - Utilize challenge goals used to guide innovation
  - Meet the Nation's needs for new technologies to support future NASA missions in science and exploration, as well as the needs of other government agencies and the Nation's space industry in a manner similar to the way NACA aided the early aeronautics industry.
  - Employ a portfolio approach over the entire technology readiness level spectrum.
  - Competitively sponsor research in academia, industry, and the NASA Centers based on the quality of the research proposed.
  - Leverage the technology investments of our international, other government agency, academic and industrial partners.
  - Result in new inventions, new capabilities and the creation of a pipeline of innovators trained to serve future National needs

- Crosscutting technologies* that may be solicited by this program include lightweight structures and materials, advanced in-space propulsion, nano-propellants, lightweight large aperture space systems, power generation/transmission systems, energy storage systems, in-space robotic assembly and fabrication systems, high bandwidth communications, and inflatable aerodynamic decelerators.

*This list is exemplary, not inclusive.

ESMD Research and Technology Development

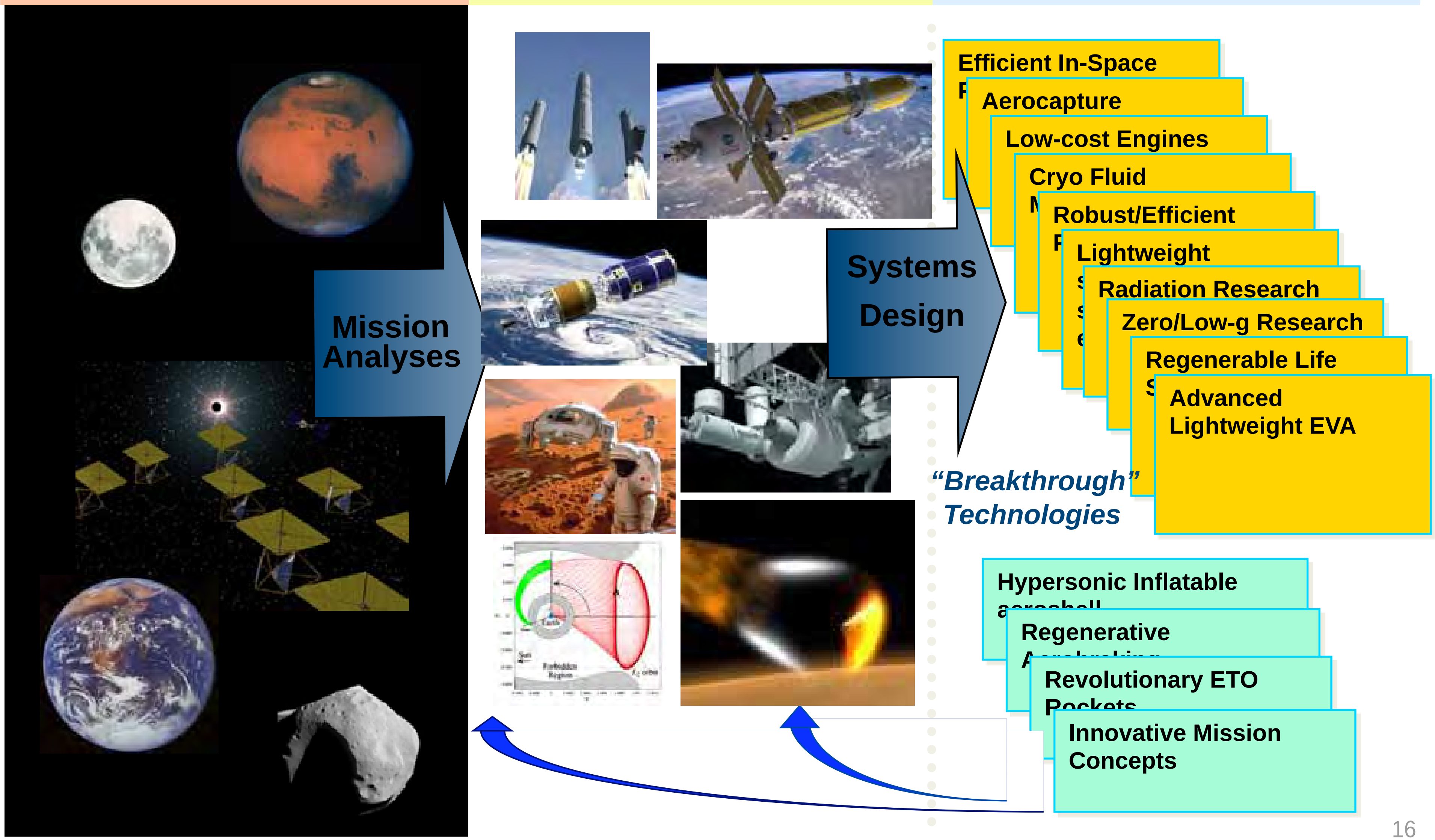
- **Exploration Technology and Demonstrations**
  - Flagship Technology Demonstration Program
  - Enabling Technology Development and Demonstration Program
- **Heavy-Lift and Propulsion Technology**
  - First Stage Engine Research and Development
  - In-space engine demonstrations
  - Foundational Propulsion Research
- **Exploration Precursor Robotic Missions**
  - Medium Exploration Class Missions
  - Small Exploration Scout Missions
  - Missions of Opportunity
- **Human Research Program**



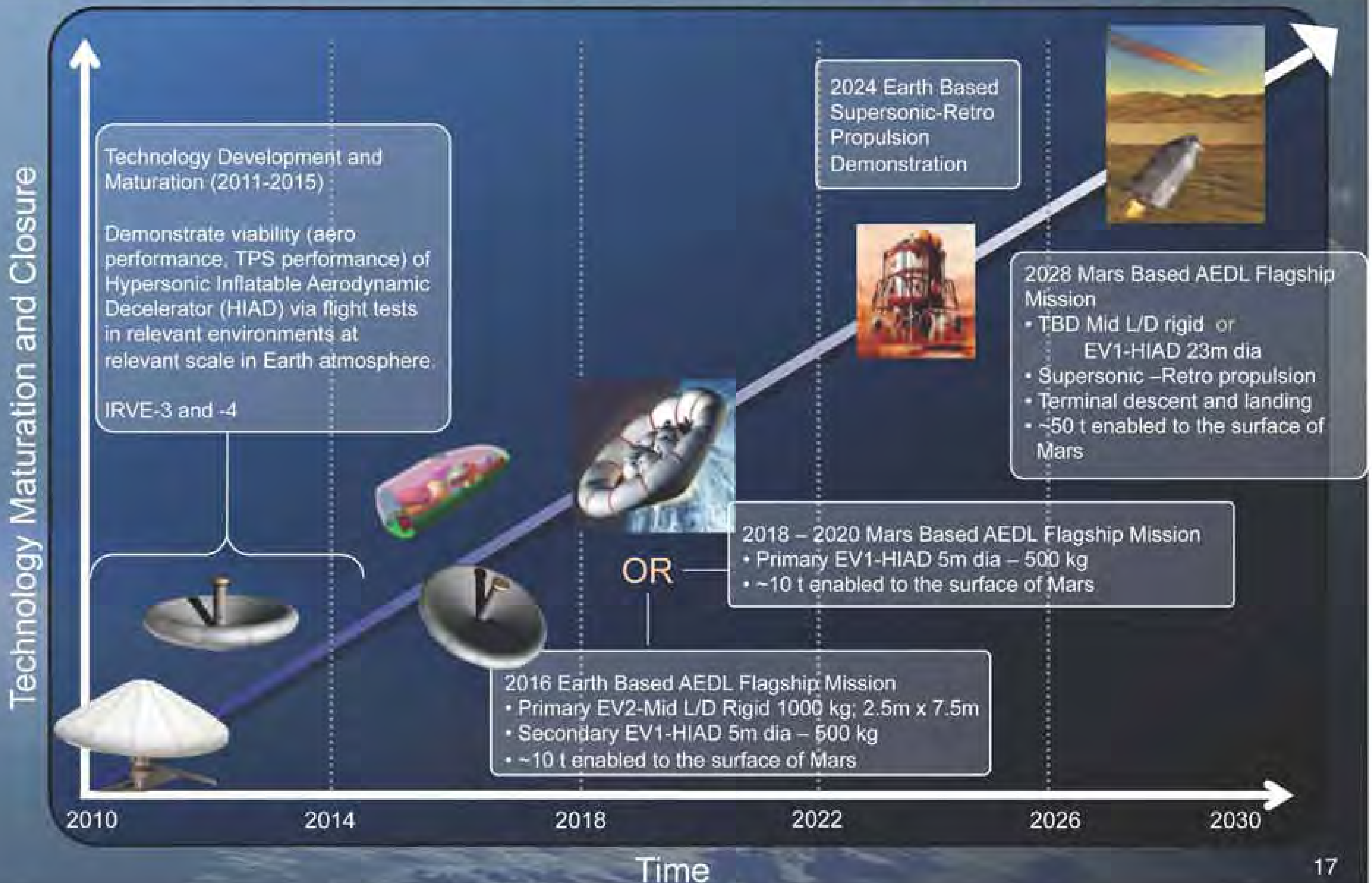


ESMD Strategy for Future Human Missions

Potential Destinations	Common Capabilities	Technology Building Blocks



Aerocapture and EDL Technology Demonstration Mission Roadmap (Preliminary)



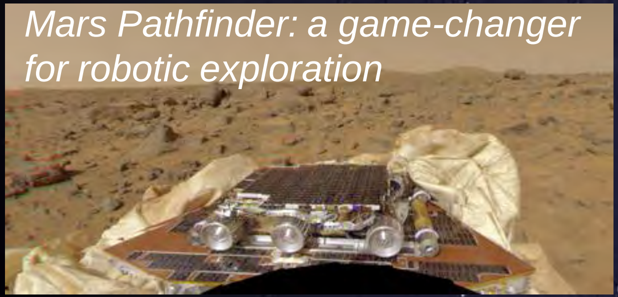
Summary

- A consistent set of external recommendations have driven the Agency's technology-enabled approach to exploration.
- NASA's planning process has produced an integrated set of technology programs that will deliver the requisite capabilities for a flexible-path exploration timeline.
  - This process is ongoing and paced for an Oct 1 program start.

NASA-Industry Inflatable Structures Collaboration

University Students Build and Fly Aluminum-ice Nanopropellant Rocket

- NASA's approach matures these technologies by moving from the technology concept and analysis phase of the past decade to a steady cadence of laboratory, flight-test and in-space demonstrations.
- These technology investments are required to infuse new capabilities into our future mission set, enabling sustainable exploration approaches.
- A NASA focused on technology and innovation,
  - Drives our Nation's economic competitiveness.
  - Serves as a strong motivation for young people to pursue STEM education and career paths.
  - Allows NASA to apply its intellectual capital to the develop technological solutions addressing broader National needs in energy, weather & climate, Earth science, health & wellness, and National security.



Mars Pathfinder: a game-changer for robotic exploration

Collaborative Measurement Spacecraft Swarms

Backup

A University Professor's View of the Near Future

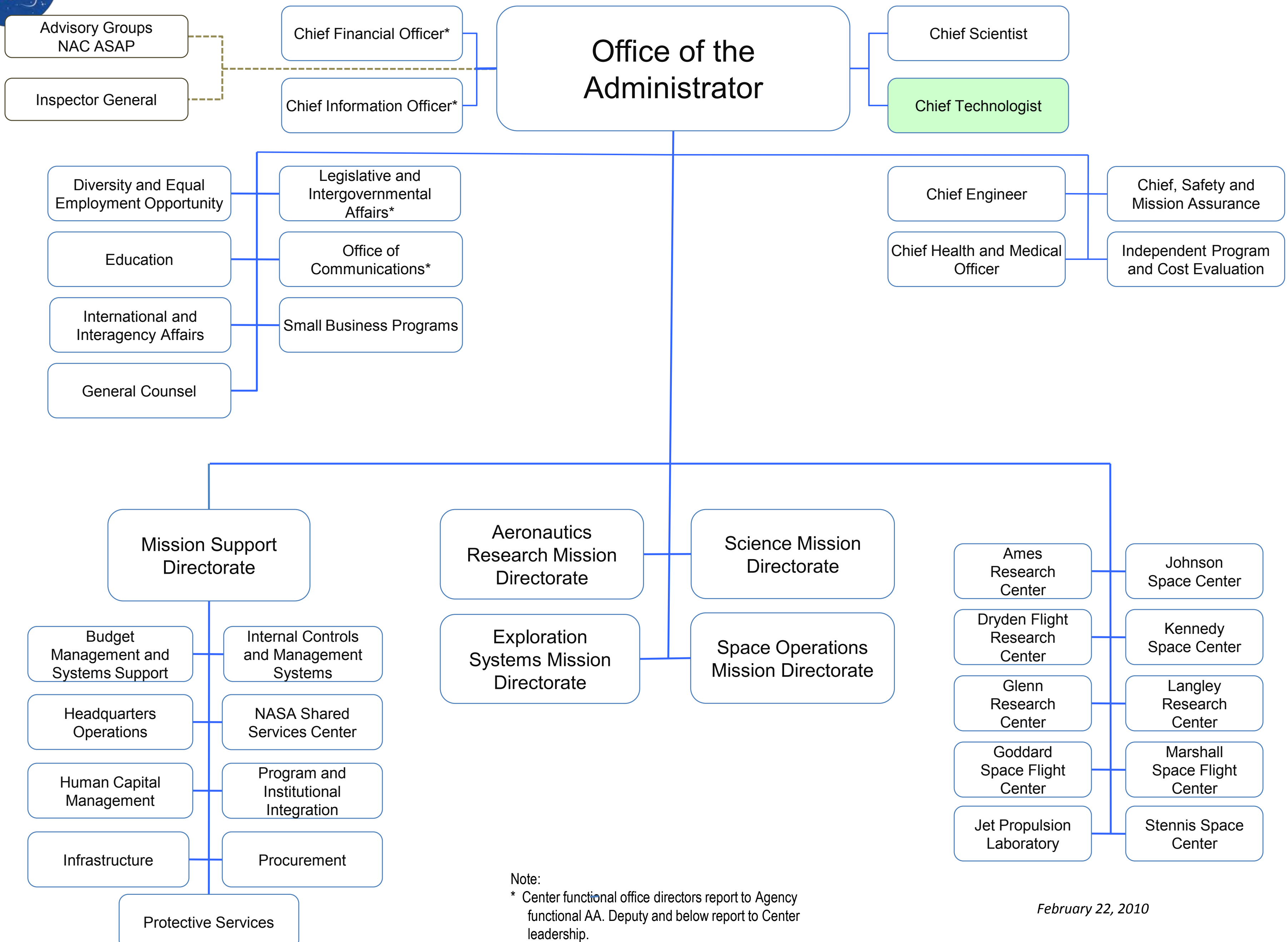
9 Examples of Game-Changing Civil Space Possibilities*:

- Quantify Causes, Trends and Effects of Long-Term Earth Climate Change
- Accurately Forecast the Emergence of Major Storms and Natural Disasters
- Develop and Utilize Efficient Space-Based Energy Sources
- Prepare an Asteroid Defense
- Identify Life Elsewhere in our Solar System
- Identify Earth-like Worlds Around Other Stars
- Initiate Interstellar Robotic Exploration
- Achieve Reliable Commercial Low-Earth Orbit Transportation
- Achieve Permanent Human Presence Beyond the Cradle of Earth

A NASA focus on Innovation and Technology is required both to enable new approaches to our current mission set and to allow us to pursue entirely new missions.

*From *Introduction to Aerospace Engineering* course notes, AE1350, R.D. Braun, Georgia Tech, Fall 2008.

National Aeronautics and Space Administration



Note:
* Center functional office directors report to Agency functional AA. Deputy and below report to Center leadership.

February 22, 2010

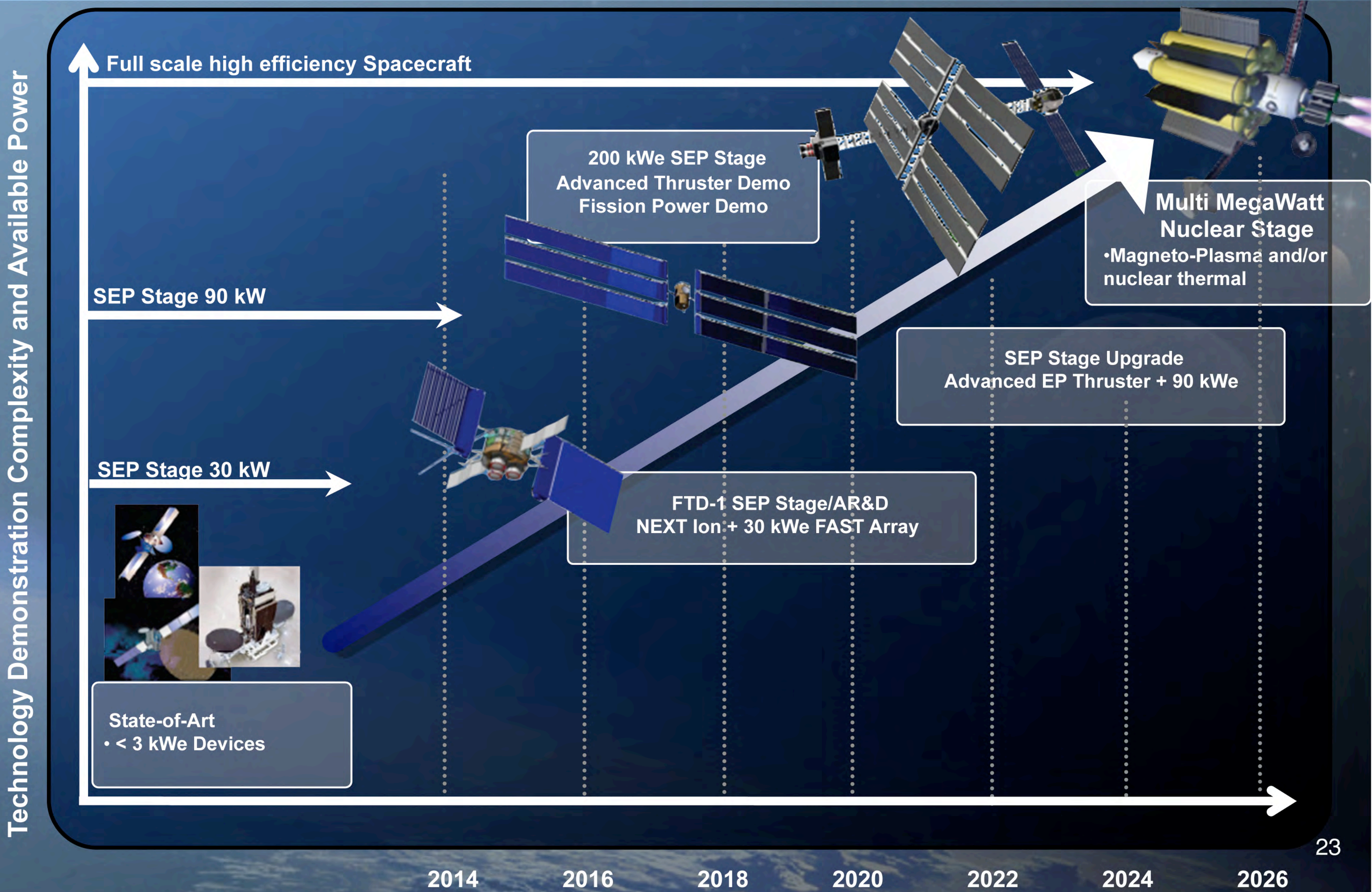
Office of Chief Technologist
Roles/Responsibilities

OCT has six main goals and responsibilities:

1) Principal NASA advisor and advocate on matters concerning Agency-wide technology policy and programs.
2) Up and out advocacy for NASA research and technology programs. Communication and integration with other Agency technology efforts.
3) Direct management of Space Technology program.
4) Coordination of technology investments across the Agency, including the mission-focused investments made by the NASA mission directorates. Perform strategic technology integration.
5) Change culture towards creativity and innovation at NASA Centers, particularly in regard to workforce development.
6) Document/demonstrate/communicate societal impact of NASA technology investments. Lead technology transfer and commercialization opportunities across Agency.

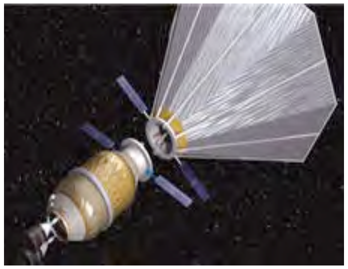
- Mission Directorates continue to manage mission-focused technology for directorate missions and future needs
- Beginning in FY 2011, activities associated with the Innovative Partnerships Program are integrated into the Office of the Chief Technologist

In Space Propulsion Technology Demonstration Mission Roadmap (Preliminary)

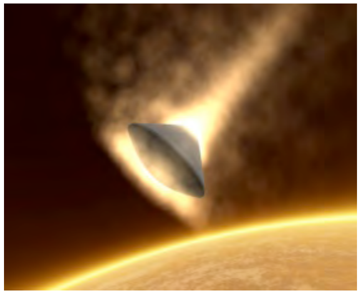


Flagship Technology Demonstrations

- Evaluation underway of highest leverage demonstrations; Mars destination is a driving case for high leverage demonstration and technology
- First three primary technology targets for single or combined missions to include:
  - In-orbit propellant transfer and storage
  - Lightweight/inflatable modules
  - Automated/autonomous rendezvous and docking



- Fourth flight program such as
  - Aerocapture/entry, descent and landing
  - Advanced life support
  - Advanced in-space propulsion (ion/plasma, etc)



- Initiate multiple technology demonstrations in FY2011
- Follow-on demonstrations informed by emerging technologies
- Identify potential partnerships with industry, other agencies, and international partners and leverage ISS for technology demonstrations, as appropriate

NASA Space Technology Program Elements

1) **Early-Stage Innovation**: Creative ideas regarding future NASA systems and/or solutions to national needs.
   - NIAC
   - Space Technology Research Grants (includes Fellowship program)
   - SBIR/STTR
   - Centennial Challenges
   - Center Innovation Fund

2) **Game Changing Technology**: Prove feasibility of novel, early-stage idea that has potential to revolutionize a future NASA mission and/or fulfill national need.
   - Game Changing Development
   - Small Satellite Subsystem Technology

3) **Crosscutting Capability Demonstration:** Maturation to flight readiness of cross-cutting capabilities that advance multiple future space missions, including flight test projects where in-space demonstration is needed before the capability can transition to direct mission application.
   - Crosscutting Technology Demonstrations
   - Edison Small Satellite Demonstration Missions
   - Flight Opportunities

*Both competitive and guided program approaches will be used in the Game Changing Technology and Crosscutting Capability Demonstration program elements. The Early-Stage Innovation program element will be entirely competed.